The University of Chicago

CONTRIBUTIONS TO THE GEOLOGY OF LATAH COUNTY, IDAHO

A PART OF A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE PHYSICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND PALEONTOLOGY
1940

By
EDWARD L. TULLIS

Reprinted from
Bulletin of the Geological Society of America
Vol. 55, No. 2, February, 1944

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FIGURE 1. VALLEY OF PALOUSE RIVER

Just above Princeton, looking east, upstream. The meandering stream may be seen in the middle distance at the right.

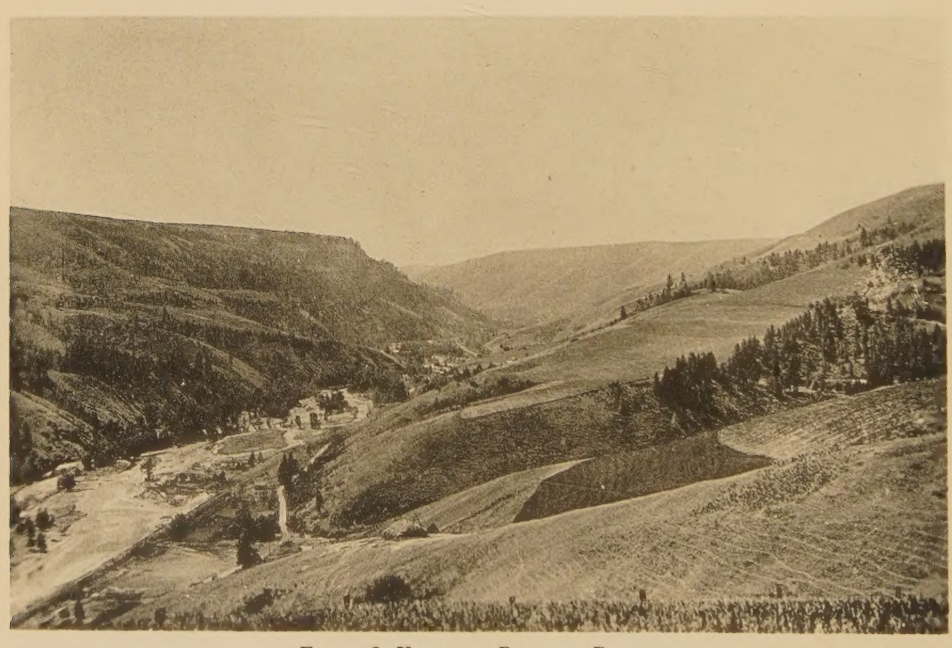

FIGURE 2. VALLEY OF POTLATCH RIVER

Near Kendrick, looking downstream. The stream is about at grade. The canyon is 1500 feet deep.

VALLEY TYPES

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BY EDWARD L. TULLIS

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ABSTRACT

Latah County lies within the Coeur d'Alene Mountains and the Columbia Plateau. The plateau is mantled with loess which is dissected into the mature Palouse topography. The origin of the Palouse Hills is considered in relation to certain newly discovered closed depressions on the tops of some of the hills. Folding of the Clearwater monocline followed deposition of the loess and rejuvenated Potlatch River.

The mountains are underlain by metamorphosed formations of the Belt series, by rhyolite and rhyodacite flows correlated with the Seven Devils volcanics, and by the Thatuna batholith correlated with the Idaho batholith. Metamorphism of the Belt rocks was dynamothermal followed by retrograde changes. The principal intrusive rock is granodiorite grading into adamellite, tonalite, and granite. Thirty Rosiwal analyses are tabulated. The order of crystallization is normal, but quartz, microcline, orthoclase, albite, and sphene have been introduced by late replacement. Most of the granite and adamellite resulted from replacement of the other types. The Gold Hill stock is more like the igneous rocks in the Coeur d'Alene district. The principal type is syenite with considerable monzonite and syenodiorite. Dike rocks with the stock include adamellite porphyry, adamellite aplite, pyroxenite, dark syenitic pegmatite, magnetite dunite, and magnetitite.

The Columbia Plateau is underlain by Columbia River basalt. Younger flows fill valleys in the Columbia River basalt and also occur 300 feet above the plateau.

The principal economic resources are residual granitic and transported clays. The geologic conditions and mineralogy suggest weathering rather than hydrothermal origin. Certain basaltic clays resulted from hydrothermal alteration.

INTRODUCTION

GENERAL STATEMENT

Latah County, in the west-central part of the "Panhandle" of Idaho, has an area of approximately 1085 square miles.

Six and one-half months was spent in the field during the summers of 1931 and 1932. The base map was compiled from the Soil Survey map, Land Office plats, U. S. Forest Service maps, and topographic maps prepared by the writer's party. The geologic mapping was done by pacing and compass traverses, supplemented by automobile traverses.

ACKNOWLEDGMENTS

The survey was an Idaho Bureau of Mines and Geology project, and the field studies were aided by members of the staff—Dr. John W. Finch, the late Dr. F. B. Laney, Dr. A. L. Anderson, and Prof. D. C. Livingston. Mr. Walter Northby was in charge of the topographic survey and aided with the geologic mapping. Acknowledgment is due members of the staff of the Department of Geology, University of Chicago, particularly Dr. R. T. Chamberlin, Dr. J Harlen Bretz, and Dr. Albert Johannsen, for advice during the laboratory work and preparation of the report. The writer is grateful to Clyde P. Ross for critical reading of the manuscript.

PREVIOUS GEOLOGIC WORK

I. C. Russell (1897), reporting on southeastern Washington, was first to discuss the geology in the area now Latah County. Later reconnaissance work was done in the southeastern part of the county by Lindgren (1904), in the area near Moscow by Laney, Kirkham, and Piper (1923), the northern part of the county by Kirkham (1927), a large area near Moscow by Johnson and Myrene (1929), and the eastern part of the county by Anderson (1930). More than 40 additional papers describe small areas or special features.

OUTLINE OF GEOLOGY OF REGION

Much of Latah County is mountainous, summits rising to 5300 feet, but the southwestern part and the valley of Palouse River below Harvard is a plateau between 2600 and 2900 feet in elevation. The mountains are spurs and bordering ridges of the ranges of north-central Idaho underlain by Belt sediments and by batholithic and associated rocks, possibly Cretaceous. At places these rocks form isolated buttes. One of these, Potato Hill, near Deary, is underlain by Permian (?) volcanics. The plateau is the projecting fingers of the basalt fields of Washington. Locally, between and beneath the flows are middle Miocene lacustrine sediments. A thick blanket of Quaternary loess covers the plateau and the lower mountain slopes. The minor streams have intricately carved the loess into mature topography, while the major streams have cut it and basalt in deep youthful valleys, at places exposing older rocks (Table 1).

PHYSIOGRAPHY

PHYSIOGRAPHIC PROVINCES

Latah County falls within the Coeur d'Alene Mountains of the Northern Rocky Mountain Province and the Walla Walla Plateau of the Columbia Plateau Province

(Fenneman, 1931, Pl. I). The boundary, drawn at the eastern margin of the Columbia River basalt, where it invades the valleys in the prebasaltic surface (Fenneman, 1931, p. 185–186), is extremely irregular as shown by the outline of the basalt on Plate 6.

TABLE 1.—*Columnar section—Latah County, Idaho*

Age	Formation	Description
Quaternary	Alluvium	Clay, silt, sand, and gravel along present streams.
	Terrace deposits	Silt, sand, and gravel on low terraces in Palouse Hills. Silt, sand, gravel, and boulders on low and high terraces in the mountains and in the basaltic canyons.
Pleistocene	Palouse "Soil"	Loess, mantling basaltic plateau and lower mountain slopes. Thickness 0-200 feet.
Miocene or Pliocene	Younger lava	Basalt and olivine basalt at levels generally above Columbia Plateau. Thickness 0-100 feet or more.
Middle Miocene	Latah formation	Light-colored sand, silt, and clay between flows of Columbia River basalt at two principal levels. Total thickness 0-350 feet.
Miocene	Columbia River basalt	Basalt and olivine basalt forming eastern margin of Columbia plateau and partly filling ancient valleys. Thickness, exclusive of Latah formation, 0-1350 feet. Bottom not exposed at all places. Maximum thickness may reach 1650 feet.
Cretaceous (?)	Thatuna batholith	Mainly granodiorite and adamellite with important amounts of tonalite and less granite, and small masses of diorite and perthosite. Numerous aschistic and diaschistic dikes, particularly pegmatites.
	Gold Hill stock	Syenite gradational into monzonite and syenodiorite. Numerous aschistic and diaschistic dikes, those of pyroxenite being of especial interest.
Permian (?)	Volcanic rocks	Flows and flow breccias, rhyolite to dacite. Thickness 1200 feet, bottom unexposed.
Algonkian	Belt Series	Quartzite, schist, and gneiss equivalent to Wallace and older formations. Thickness 40,000 feet, bottom unexposed.

REJUVENATION OF POTLATCH DRAINAGE

The streams are of two groups: (1) those that flow southward into Clearwater River, chiefly by way of Potlatch River, and (2) Palouse River and its tributaries draining westward to Snake River. The middle and lower courses of Palouse River (Pl. 1, fig. 1) are in a valley partly filled by basalt and have low gradients.

Potlatch River also flows on basalt but has a different profile. In its upper 10 miles it falls 15 feet per mile. The gradient increases to 87 feet per mile for 16 miles between Bovill and Pine Creek and below the latter point decreases to 37 feet per mile at Juliaetta, where the canyon is 1500 feet deep (Pl. 1, fig. 2). The knickpoint near Bovill seems unrelated to structure. In the sluggish upper parts the tributaries are in Palouse loess, and the floors are terrace and floodplain deposits. In the middle

courses the streams have cut through the loess into basalt, leaving remnants of terraces. In the lower courses no terrace remnants are found in the loess high on the basaltic rims. The soil maps of Latah County (Agee, Graves, and Mickelwaite, 1917) and of Nez Percés (Agee and Peterson, 1920) and Lewis counties demonstrate the relationships. The sequence of events is clearest in the counties to the south.

South of Latah County Potlatch River is consequent on the Clearwater monocline (Russell, 1901, p. 72), where the dips of the basalt are steep (Kirkham and Johnson, 1929, p. 491–492, sta. 24). At that place the position of the stream probably is little different from that before the formation of the monocline. The profiles of the streams and relationships of the youthful canyons to the hills and flood plains of the mature Palouse topography support a hypothesis that the Potlatch drainage was rejuvenated by formation of the monocline. The effect of the folding would not have been felt immediately unless Snake River could maintain its northward course across the rising monocline near Alpowa, Washington. There is no evidence of damming there.

AGE OF THE CLEARWATER ESCARPMENT

The Palouse loess was deposited and maturely dissected before folding of the Clearwater escarpment rejuvenated the drainage. Thus the earliest age of the escarpment is fixed by the age of the loess, which is Pleistocene (Bryan, 1927). Several points of evidence indicate that the loess probably was deposited before late Pleistocene (Bretz, 1929, p. 396; Krynine, 1937; Scheid, 1940b).

ORIGIN OF PALOUSE HILLS

Description of topography.—All descriptions of the Palouse region record the unusual topography. It is mature, with relief of about 250 feet (Pl. 2, fig. 1). Many of the hills enclose northeast-facing amphitheaters, and northeastern slopes are steeper than southwestern. Most writers have emphasized the preponderance of concave slopes, with convex slopes only near the tops of hills. The flat-bottomed valleys are dry except along the larger drainage lines.

Hilltop depressions.—One unreported feature is the broad shallow depressions on the summits of some of the rare hills that have wide, flat tops (Pl. 2, fig. 2). Ten of the depressions in the southwestern part of the county are shown on Figure 1. They are circular to slightly oval with diameters of 100 to 500 yards and depths of 5 to 30 feet. The oval ones are not uniformly oriented. There is only a slight variation in elevations on the rim of any one depression, and no direction can be detected as a consistently low side on the rims. The basins contain water during the rainy season, and one of them has a permanent lake. One or two depressions reported to contain water within the previous 15 years are now drained by a narrow bottle neck along a shallow gully through the rim. Four or five other hilltops have forms gradational between closed depressions and shallow amphitheaters drained by narrow breaches.

The origin of the depressions probably is related to the origin of the Palouse soil, and recent investigators agree that this material, or at least its surface portions, is aeolian. The lack of marked elongation or consistent orientation is against formation as blow-outs. With the present amount of precipitation, a slight depression

holds sufficient moisture to prevent wind erosion. In this region, at least under present conditions, the dominant process seems to be deposition rather than erosion, except for minor shifting. Rockie (1933) suggests that the heavy-textured Palouse soil is little subject to wind erosion unless precipitation is less than 18 inches per year,

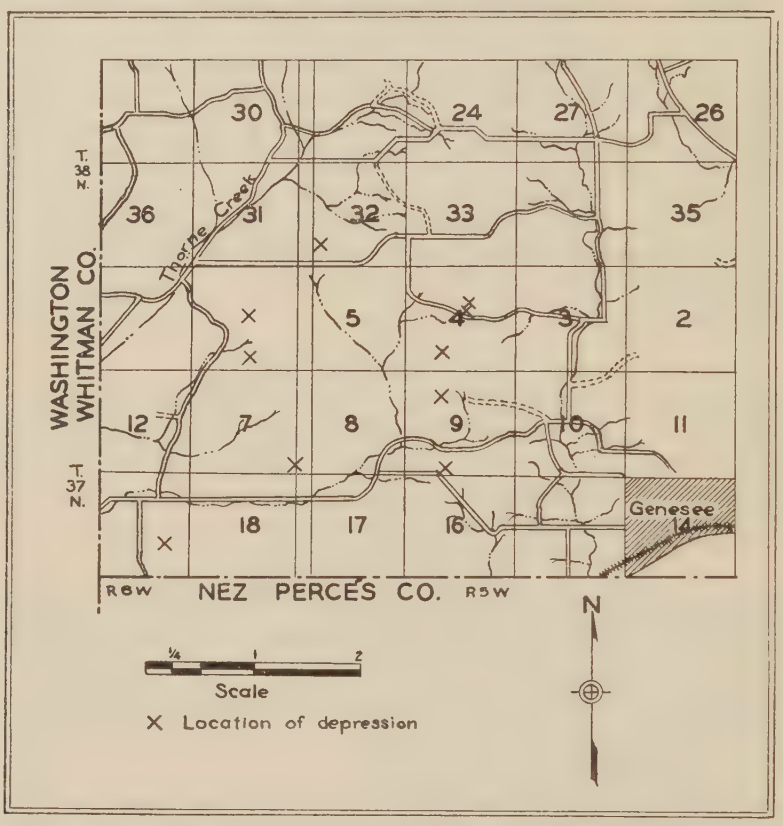

FIGURE 1.—*Map of the southwestern corner of Latah County*

Shows location of depressions on tops of Palouse Hills

and not even then unless there is no vegetation. The average annual precipitation at Moscow is about 22.5 inches.

It seems more probable that the basins resulted from inequalities of original deposition and distribution. It is difficult to know the cause of such inequalities, but perhaps it might be variation of distribution of vegetation during soil deposition, with resultant effect upon moisture content of the soil and upon local shifting by wind. The basins are on hilltops only near the highest part of the Uniontown Plateau, probably because erosion has not worked headward far enough to dissect the covering of loess completely.

Landslides.—Small landslides of the types shown in Figure 3 of Plate 2 are common on steepest slopes of the Palouse hills in the spring when the loess is saturated with water.

Origin.—Russell (1897, p. 66–67) suggested that the hills are the product of running water with modification by wind. Kirkham, Johnson, and Holm (1931), by a statistical study of orientation of amphitheaters, confirmed the fact that these face chiefly northeast, east, or north. Noting the resemblance to cirques, they proposed a snowbank nivation origin. As minor factors they recognized soil-slip, slump, mudflow, and rill erosion. The steepening of upper walls by landslides (Pl. 2, fig. 3) may be a factor not sufficiently emphasized. Study of the hilltop depressions shows that the amphitheater is encountered from the first drainage of the depressions through breaches in the rims. Orientation of the amphitheaters is random, but nivation favors perfection of those facing northeast.

METAMORPHISM OF THE BELT SERIES

GENERAL DESCRIPTION

The Belt rocks occur in two continuous but structurally separable parts of the county. The northern part includes the area from the Thatuna Hills northward, the Hoodoo Mountains, and the hills along the eastern margin north of Bovill. The structure is simple, a few major folds modified by minor folding and faulting. In the southeastern part of the county noses of large folds extend westward from Clearwater County. At least 15 isolated areas also were mapped south of the Thatuna Hills and west of Potlatch Canyon.

Eight separate formations were distinguished, but two of those in the southeastern district may be equivalent to those in the northern. They are summarized in Table 2. The Belt rocks may aggregate 40,000 feet in the northern part of the county and about 10,000 feet in the southern area.

PETROGRAPHY

Metamorphism has produced two principal types: (1) rocks containing chiefly quartz, mica, and feldspar, and (2) rocks containing chiefly quartz, diopside, or actinolite (including tremolite), feldspar, subordinate mica, and some sphene. Scapolite occurs in both but usually accompanies diopside or actinolite, and zircon and tourmaline are common in both types. The paragneiss (Table 2), gray quartzite, and most of the schist belong in the first type, while the diopside quartzite, granular quartzite, and certain layers of the schist belong in the second.

The andalusite schist that extends north and northeast from Mica Mountain to the head of the North Fork of Palouse River gives a key to the metamorphism. The rock contains numerous medium-gray, flat, irregular to diamond-shaped masses about 5 mm. thick and up to 3 cm. in diameter. In thin section the matrix resembles the schist in other parts of the formation. The gray masses are largely quartz and sericite of much finer grain than the matrix. In each gray mass are scattered ragged but optically oriented pieces of andalusite, once obviously continuous but now partly altered to quartz and sericite. In one gray mass a piece of kyanite was found, and in another section were discontinuous but optically oriented pieces of staurolite in a matrix of sericite. At many places garnet and biotite are partly altered to chlorite.

TABLE 2.—*Description of rocks of Belt Series in Latah County, Idaho*

Northern and northeastern areas

General character	Mineralogy	Relations to other formations	Distribution
Gray quartzite. Light to medium shades. Fine-grained. Well bedded, with ripple marks, Schistose in lower part. Light-gray to blue-gray argillite at places in upper part. Metamorphosed to light green at places near igneous contacts and to dark hornfels with white spots 1–1½ mm. in diameter. Total thickness probably more than 30,000 feet.	Quartz and sericite most common; biotite abundant; alkali feldspar (chiefly albite), tourmaline, zircon, and magnetite common; siderite rare. Spotted hornfels is similar in composition except that the spots are of quartz and andesine or quartz and scapolite. Muscovite and epidote may occur. The green rock consists of quartz, feldspar, and actinolite, rarely with diopside and sphene.	Top not present. Grades downward into schist.	Underlies most of the area of metamorphic rock north of Thatuna batholith and west of line connecting North Fork of Palouse River with Yale railroad station.
Mica schist. Silvery gray. Fine- to medium-grained. Thickness 4000 feet. Four hundred feet above bottom of formation is bed of andalusite schist 650 feet thick not present everywhere.	Chiefly quartz, muscovite, and biotite. Acid plagioclase, scapolite, garnet, and clinozoisite frequently occur in considerable quantity, but not universally present. Crystals of magnetite, tourmaline, and zircon generally present and locally numerous. Actinolite or tremolite abundant in some parts and at places forms metacrysts. Chlorite rare. Andalusite schist contains quartz, biotite, magnetite, chlorite, zircon, garnet partly altered to chlorite, andalusite largely altered to quartz and sericite. Cyanite and and staurolite altered to sericite are rare.	Grades upward into gray quartzite and downward into granular quartzite.	Underlies a belt 1½–5 miles wide extending northeast from Mica Mountain to county line and from there eastward to headwaters of Emerald Creek. Smaller areas occur on east slope of Beals Butte, in a triangular area between Collins and Bovill, and south of Potlatch on north side of Thatuna batholith. Complete section is exposed along North Fork of Palouse River.
Granular quartzite. White to greenish. Largely banded with green a fraction of inch to a few feet thick between thicker bands of white quartzite. Fine- to medium-grained. 5000–6000 feet thick.	Chiefly quartz with much albite and a little diopside. Green beds contain mainly quartz, albite, microcline, diopside, and tremolite. Scapolite, actinolite, calcite, and occasionally biotite, instead of diopside, are abundant. Sphene and zircon common. Allanite and olivine rare.	Grades upward into schist. Bottom not exposed.	In the Hoodoo Mountains the formation occupies crest of an anticline, with east limb on Beals Butte and west limb along upper Palouse River. Also forms east limb of syncline along east border of county.
Southeastern and southern areas			
Paragneiss. Coarse-grained silvery-gray, weathers to silvery pink or yellow. 5000 feet thick or less.	Quartz more than half the rock, plus equal amounts of muscovite and biotite. Microscopic crystals of apatite, zircon, and sphene common. Half the sections contain alkali feldspar up to 25 per cent of total. Andalusite and garnet rare.	Seems to overlie diopside quartzite with gradations. Probably faulted against granular white quartzite north of Ruby Creek. Top not discovered. Grades laterally into mixed gneiss in Bear Canyon.	Prominent ridge maker forming Tamarack Ridge and Big Bear. Underlies hills immediately surrounding Round Meadow.

TABLE 2.—*Continued*

Southeastern and southern areas

General character	Mineralogy	Relations to other formations	Distribution
Diopside quartzite. Light green. Fine- to medium-grained. At places interbedded with mica schist. 5000 feet thick or less.	Quartz and diopside most abundant. Scapolite, albite, and microcline common. Other feldspars present at places. Sphene generally occurs, zoisite and zircon often present. Calcite occurs in small amounts in many specimens. Biotite common at places. Muscovite, tremolite, olivine, and garnet rare.	Appears to rest on white crystalline quartzite and to be overlain by paragneiss.	East of Crescent along western end of Alderman's Ridge and into Three Bear Valley. Divide at headwaters of Boulder, Little Boulder, Three Bear, and Long Meadow creeks. South of Ruby Creek.
White crystalline quartzite. Massive and well jointed. Bedding not apparent. Resembles vein quartz. 100–500 feet thick.	Almost entirely quartz, cataclastic texture common. A little tourmaline, muscovite, apatite, and zircon.	Appears to underlie diopside quartzite.	Viola Ridge, Mason Butte, Tomer Butte.
Amphibolite. Black to dark green studded with pink garnets. Medium- to fine-grained.	Chiefly hornblende with abundant garnets, moderate to small amounts of quartz, and a little plagioclase, biotite, and magnetite.	Small bodies enclosed in mixed gneiss.	Cedar and Boulder valleys.
Mixed gneiss. Alternate bands of medium to coarse igneous material and of schist. Similar to parts of border of Idaho batholith to southeast. Banding not present everywhere.	Igneous bands of biotite tonalite, occasionally with hornblende instead of biotite. Sillimanite rare. Schistose bands contain quartz, biotite, muscovite, and alkali feldspar. Unbanded rock contains diopside or actinolite in addition.	Banded portions probably equivalent to paragneiss. Unbanded portions probably equivalent to diopside quartzite.	At places in bottoms of canyons of Potlatch and Little Potlatch rivers and of Dry, Bear, and Little Bear creeks.

METAMORPHISM

The quartz, mica, and feldspar type is similar to the noncalcareous rocks of the Pend Oreille district described by Gillson (1930), and the second type with quartz, diopside, actinolite, feldspar, mica, and sphene is similar to his calcareous rocks. The Latah County beds are siliceous almost throughout, and their mineralogical variation probably depends upon the ratio of calcareous or argillaceous materials to quartz in the original formations.

Possibly part of the feldspar is detrital, but the writer believes that most of it was introduced by magmatic solutions. Complete recrystallization makes the problem difficult, but the hypothesis of magmatic solutions is supported by: (1) the almost universal presence of feldspar despite its irregular distribution and variable quantity within any formation; (2) the fact that it is almost entirely alkali feldspar; and (3) the presence of other minerals believed to be secondary: tourmaline, scapolite, and zircon.

The first metamorphism was dynamothermal, the thermal element increasing in importance with time. Abundant actinolite and tremolite in several formations and remnants of cyanite and staurolite in andalusite schist attest the early importance of the dynamic element. Later, cyanite probably changed to andalusite (Harker,

1939), and staurolite to cordierite, subsequently entirely destroyed. Such changes would occur by thermal metamorphism during or just after emplacement of the batholith. Next the andalusite and staurolite (and possibly cordierite) altered to sericite and quartz, and garnet and biotite partly changed to chlorite. This "retrograde" metamorphism (Schwartz and Todd, 1941) possibly occurred during the cooling stages, perhaps fostered by magmatic solutions. Such solutions permeated widely, adding alkali feldspar, tourmaline, scapolite, and zircon.

CORRELATION

Positive correlation must await work in areas to the north and northeast, because metamorphism prevents correlation by lithology. Certainly the Wallace and possibly the Burke, Revette, and St. Regis formations are included in the gray quartzite. Their maximum thickness measured elsewhere (Umpleby and Jones, 1923, p. 7–8) is less than half the 30,000 feet estimated for the gray quartzite. Either the Coeur d'Alene section thickens to the south or younger beds are present.

The above suggests that the schist and granular quartzite in the Hoodoo Mountains are of the Prichard formation as contended by Livingston (Livingston and Laney, 1920). The white crystalline quartzite may represent another quartzitic member of the Prichard.

Possibly the paragneiss and diopside quartzite of the southeastern district may be equivalent to the schist and granular quartzite respectively, but differences make the suggestion doubtful.

PERMIAN(?) VOLCANICS

GENERAL DESCRIPTION

Two types of volcanic rocks are found in the group of hills just north of Deary. The porphyritic, light-pink, lavender, gray, and dark-purple type ranges from rhyolite to dacite and occurs at the margins of the hills except on the south. Good exposures occur on the end of the ridge northwest of Potato Hill and on the end of the ridge to the east. Occasional outcrops are found west of Vassar Meadow, along the Avon road.

The other type, a dark-purple to black flow breccia, appears to overlie the first and forms the bulk of Potato Hill. The upper part of the hill is composed of flows which dip 14° to 20° W., and the western slope is largely a dip slope. The strike varies between N. 30° W. and N. 20° E.

In addition to the large area north of Deary, there are two other small isolated outcrops: (1) an inlier in the Miocene basalt just south of Deary, and (2) the low hill within the large loop of Potlatch River a mile southwest of Bovill.

No exact thicknesses are known. The flow breccia on Potato Hill was estimated to be 950 feet thick, and the porphyritic flows possibly are 200 or 300 feet thick.

PORPHYRITIC FLOWS

There are light and dark flows. The former have pink to lavender groundmass with cream feldspar phenocrysts up to 3 mm. long, spaced at about $1\frac{1}{2}$ to 2 cm. The few quartz phenocrysts do not exceed 1 mm. in diameter. The dark flows are purple to bluish gray with stony groundmass containing closely spaced light-yellow feldspar

FIGURE 1. PALOUSE TOPOGRAPHY

Looking northward from "Jain," the U.S.G.S. triangulation station in southwestern Latah County.

FIGURE 2. DEPRESSION ON TOP OF A PALOUSE HILL

The distance across the depression to the bushes on the horizon is about ¼ mile. The depression is 30 feet deep and contains a permanent lake.

FIGURE 3. LANDSLIDE

Vertical face formed at head of slide-scar is 6 feet high. Soil has slid only from the steepest part of the hill, and in the slide are numerous large unslaked chunks of loess. The amphitheater faces north.

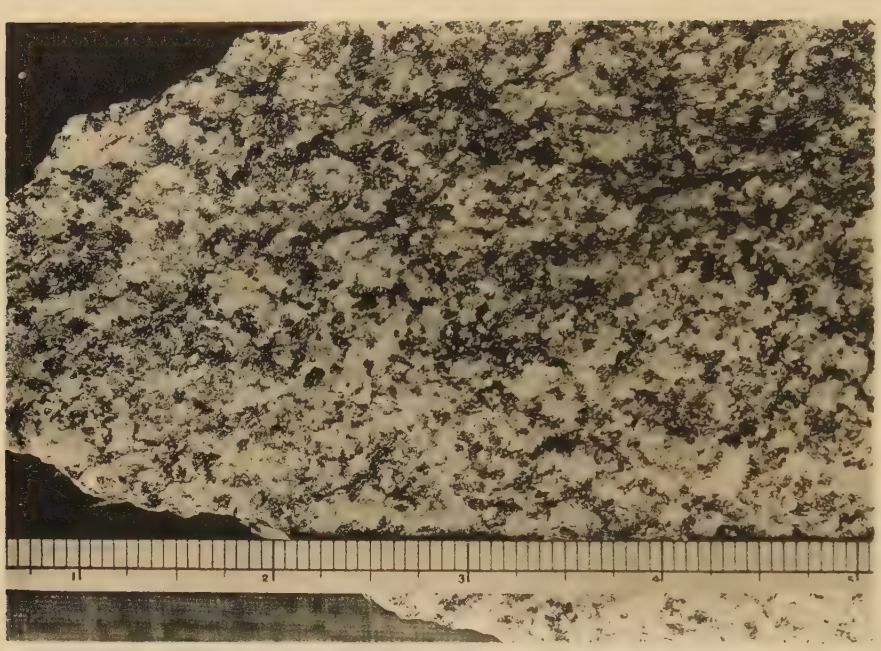

FIGURE 1. TYPICAL GRANODIORITE

From the Thatuna batholith, near Troy. Minerals are quartz, feldspar, and biotite (specimen 14, Table 4).

FIGURE 2. PORPHYRITIC ADAMELLITE

Field photograph of outcrop near Joel. Phenocrysts are microcline (specimen 24, Table 4).

phenocrysts up to 2 mm. long. In some specimens the phenocrysts are less abundant and include quartz, glassy feldspar, and cloudy, white, or light-green feldspar.

The predominant phenocrysts are orthoclase and plagioclase, which varies from $Ab_{90}An_{10}$ to acid andesine. Most of the feldspar shows resorption (Pl. 5, fig. 1). Quartz never exceeds the feldspars. Magnetite is angular. The total quantity of phenocrysts averages about 6 per cent. The groundmass, originally hypohyaline, is devitrified. It is dominantly feldspar and quartz in ratios ranging between 3:1

TABLE 3.—*Chemical analyses of Permian(?) volcanics*

	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	Ignition loss	Total
No. 1	69.44	15.68	3.90	0.86	1.18	3.26	4.40	1.34	100.06
No. 2	71.68	15.06	1.90	0.38	0.34	3.04	5.74	1.72	99.86

1. Rhyodacite, Potato Hill. 2. Rhyolite, Potato Hill. Analyst: Charles Bentley, South Dakota School of Mines and Technology.

and 4:1. Feldspar is predominantly orthoclase with some acid plagioclase. Other minerals are magnetite, apatite, and zircon. Magnetite exceeds 5 per cent. The secondary minerals are white mica, kaolin, limonite, and hematite.

The flows are mainly rhyolite to dellenite and possibly dacite. One specimen each of rhyodacite and alkali rhyolite was found. Chemical analyses are required to determine many specimens. Analyses of two samples, from the ridge northwest of Potato Hill, are given in Table 3.

Specimen No. 1 is the dark rock. The norm is quartz 29.2 per cent, orthoclase 27.8 per cent, plagioclase 33.6 per cent, and femic minerals 6.0 per cent. The molecular ratio of albite to anorthite indicates andesine or oligoclase, and the microscope shows oligoclase ($Ab_{80}An_{20}$) phenocrysts. Specimen No. 2 is the light rock. The norm is quartz 31.2 per cent, orthoclase 33.9 per cent, plagioclase 26.5 per cent, and femic minerals 2.9 per cent. Molecular ratio of albite to anorthite indicates albite or oligoclase, and the microscope shows oligoclase phenocrysts. On the basis of the norms, No. 1 is rhyodacite and No. 2 is rhyolite, or both may be called dellenite.

FLOW BRECCIA

This type is purple to black, spotted with light inclusions an inch or less in average size, but ranging up to more than a foot. The dark matrix is of dense, angular inclusions, purple, black, and dark brown, cemented with the same type of material. The dark inclusions in turn contain others. Both matrix and dark inclusions have a few phenocrysts of feldspar, up to 3 mm. long, and round phenocrysts, or inclusions of quartz.

The microscope shows about half the volume to be unbrecciated glassy matrix. The larger inclusions are fragments of breccia cemented with glass. The other inclusions are fragments of sedimentary and igneous rocks. The matrix bears little resemblance to the porphyritic rhyolite flows. Except for globulites and a few spherulites, the groundmass is almost entirely cryptocrystalline. One flow may be dacite, suggested by abundant hornblende in the groundmass. Variation in index

of refraction of the devitrified glass indicates considerable range in composition. All of the rocks are quartz-bearing.

CORRELATION AND AGE

No exact age determination can be made. They are younger than pre-Cambrian metamorphic rocks and older than the Cretaceous (?) batholith. On a reconnais-

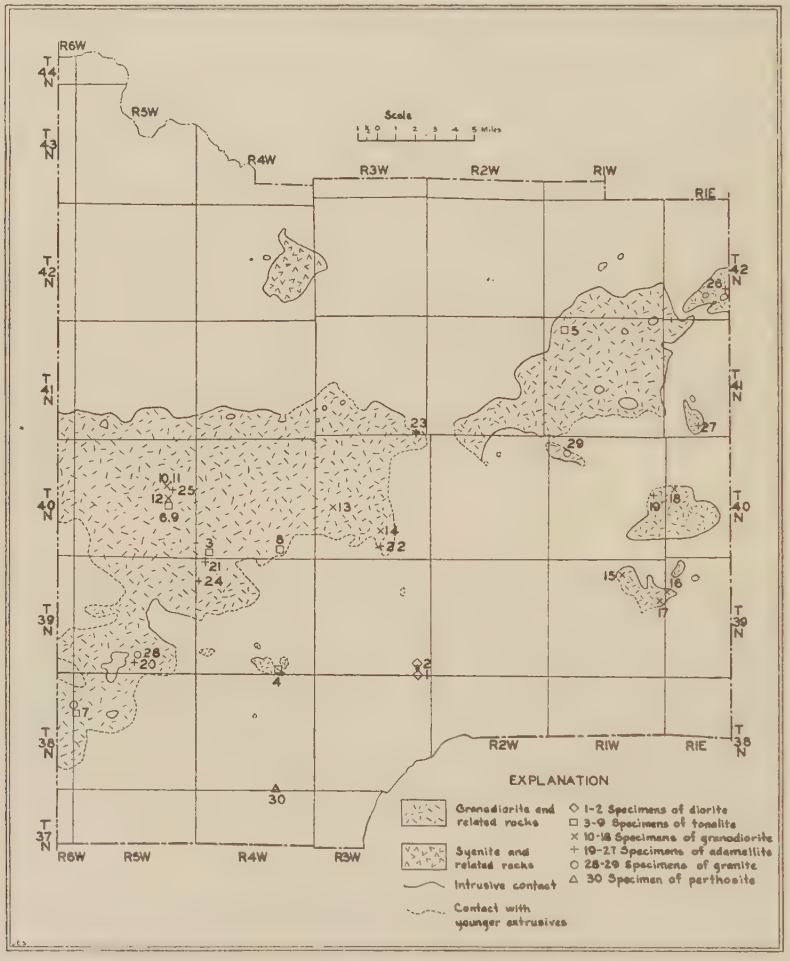

FIGURE 2.—*Map of igneous intrusions of Latah County*
Shows distribution of analyzed specimens

sance map of the Clearwater region Anderson (1930) shows the rocks by the same symbol as the Permian Seven Devils volcanics.

CRETACEOUS(?) INTRUSIVE ROCKS

GENERAL STATEMENT

The plutonic rocks are: (1) quartz-bearing, the dominant type, chiefly granodiorite plus important amounts of adamellite and tonalite and minor amounts of granite;

(2) quartz-free, or nearly so, including syenite and more basic types. The first type is found in the Thatuna batholith and as stocks in the southeastern area. Two small areas of diorite and perthosite are shown by the same map symbol. The second type occurs only in the Gold Hill stock (Fig. 2).

THATUNA BATHOLITH

Extent.—A large area of intrusive rock extends across the county through the Thatuna Hills and Paradise Ridge and over the State line to Bald Butte, Washington. The area in Idaho is about 212 square miles, and the exposure probably was 30 to 50 per cent greater before extrusion of the basalt. Since the plutonic mass is many miles from and independent of the Idaho batholith, it is here called the Thatuna batholith.

Granodiorite and related rocks.—The Thatuna batholith is essentially uniform in composition over large areas, but as a whole is far from constant. Granodiorite, adamellite, tonalite, and granite each make considerable masses and form the principal intrusions. Of the many specimens collected from the batholith and stocks, 29 were studied microscopically, excluding hypabyssal bodies and the Gold Hill stock, described in later sections. The locations of the specimens are shown in Figure 2.

The typical light-gray rock is shown in Figure 1 of Plate 3. Many specimens, particularly those of adamellite, contain less than 5 per cent dark minerals and frequently are cream or almost white. The texture is granular but may be gneissic or porphyritic (Pl. 3). Most of the visible grains are between 1 mm. and 5 mm., averaging a little more than 2 mm. The stocks south of Bovill and north and east of Park are medium- to fine-grained, averaging about 1.5 mm. Phenocrysts vary from 3 mm. to more than 3 cm. but average about 2 cm. Megascopically the principal minerals are quartz, feldspar, and biotite. Muscovite often occurs, and occasionally garnet and epidote. Hornblende is common only in quartz-free types. Sphene and tourmaline are rare except microscopically.

The mineralogical composition, determined by the Rosiwal method, is given in Table 4, and the positions of the rocks on a Johannsen (1939) triangular diagram are shown in Figure 3. Field observations show that granodiorite is dominant. Averages of the three principal families are the last three rocks in Table 4.

Diorite.—Diorite forms the southern half of an inlier along Bear Creek southwest of Atwater Lake. The exposure is stained reddish-brown, but fresh specimens show light cream-colored plagioclase speckled with green hornblende. The grains range between 1 and 3 mm. Two specimens (Nos. 1 and 2) are included in Table 4 and Figures 2 and 3.

Perthosite.—Perthosite (Phemister, 1926) crops out as an inlier near Pine Grove School between Genesee and Juliaetta. It is light cream-colored and medium-grained, with feldspar crystals up to 5 mm. but averaging $1\frac{1}{2}$ mm. The texture is xenomorphic-granular (Pl. 4, fig. 2). Microcline-microperthite and cryptoperthite dominate accessory magnetite and apatite and a few small segregations of a ferromagnesium mineral, altered beyond recognition. Microcline-microperthite shows albite ($Ab_{95}An_5$) in spindles and as ramifying veinlets. Rosiwal analysis shows the ratio of potash feldspar to visible albite in the microcline-microperthite to be 2:1.

Origin of rock types.—In most of the rocks the order of crystallization is constant. First minerals are magnetite, apatite, and zircon. Most of the augite has been converted to hornblende. Hornblende and plagioclase are partly contemporaneous. Biotite overlaps hornblende, and potash feldspar and quartz are later than biotite. Generally microcline formed after all other minerals (Pl. 4, fig. 1) but at places is older than quartz.

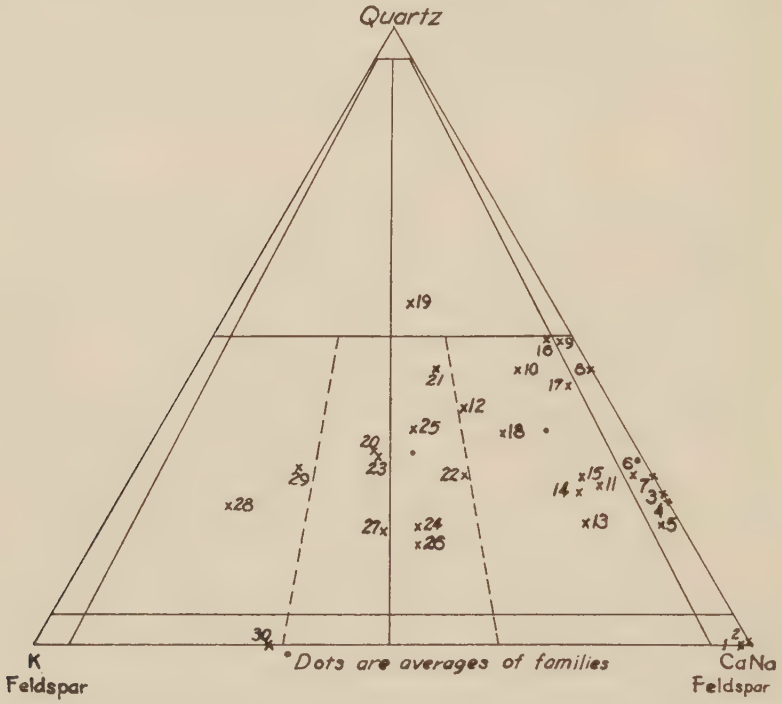

FIGURE 3.—*Triangular diagram of modes of plutonic rocks*
Plotted according to Johannsen's system

Anderson and Hammerand (1940) have described intensive endomorphism in a few square miles on Paradise Ridge. Hornblende-biotite diorite has been hydrothermally converted to biotite-quartz diorite and granodiorite. The textural evidence they describe is duplicated in the writer's specimens.

In most of the Thatuna batholith the chief late replacement minerals are quartz and microcline (Pl. 4, fig. 1) with less orthoclase and albite and scattered sphene. Microcline, orthoclase, and quartz replace all minerals, but microcline particularly attacks plagioclase and biotite. It is difficult to estimate how much microcline formed by replacement, but textural evidence suggests that most of it did.

Tonalite and granodiorite appear to be parts of the batholith as it originally solidified, except locally as on Paradise Ridge. The principal potash feldspar is orthoclase, mostly pyrogenic. The ratio of microcline to orthoclase is less in tonalite and granodiorite than it is in adamellite and granite (Table 4, analyses 31–33). The latter rocks have formed by replacement of the former by microcline.

TABLE 4.—*Volumetric modes of plutonic rocks of Latah County*

	1	2	3	4	5	6	7	8	9	10	11
Quartz	.....	0.6	22.1	21.9	19.1	23.0	24	38.2	38.7	42.7	22.6
Andesine	48.2	.....	68.3	70.2	.....	58.8	65	47.2	.....	.....	.....
Oligoclase	.....	.....	.....	.....	72.9	.....	.....	.....	38.4	.....	52.3
Albite	2.7	1.1	.....	.....	.....	.....	.....	.....	.....	37.4	.....
Antiperthite	35.0	89.4	.....	.....	.....	.....	.....	.....	9.9	.....	2.4
Microcline	x	.....	.....	.....	.....	1.9	.....	.....	2.0	1.5	6.9
Microcline-microperthite	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cryptoperthite	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Orthoclase	1.1	x	x	.....	2.6	0.5	.....	.....	0.3	5.5	0.5
Microperthite	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.0	.....
Biotite	x	0.7	7.2	4.7	0.5	14.2	9	10.0	7.2	.....	5.1
Muscovite	.....	.....	1.1	2.5	.....	0.2	1	2.2	0.4	3.8	6.0
Hornblende	10.7	6.5	.....	.....	1.6	0.3	.....	.....	x	.....	.....
Augite	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Magnetite	x	.....	x	x	x	0.3	x	.....	0.3	.....	x
Apatite	.....	0.1	x	0.4	x	x	x	x	x	x	x
Sphene	1.2	0.1	.....	.....	0.1	0.9	x	.....	0.2	.....	.....
Zircon	x	x	x	0.1	0.1	.....	x	x	x	x	x
Monazite	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Garnet	.....	.....	.....	x	x	.....	.....	.....	x	.....	.....
Ilmenite	.....	.....	.....	.....	.....	.....	.....	x	.....	.....	.....
Rutile	.....	.....	.....	.....	.....	.....	x	x	.....	.....	.....
Allanite	x	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Tourmaline	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Secondary white mica	.....	x	x	.....	x	x	x	0.8	0.3	6.1	4.2
Kaolin	x	x	x	x	x	x	x	x	x	x	x
Epidote	0.1	1.5	1.3	.....	0.3	x	x	.....	2.2	x	.....
Chlorite	.....	.....	x	0.2	x	x	.....	1.5	x	.....	x
Limonite	.....	.....	x	.....	x	.....	.....	.....	.....	.....	.....
Hematite	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Calcite	.....	.....	.....	.....	.....	0.2	.....	.....	0.4	.....	.....
Zoisite	0.6	.....	x	.....	x	x	.....	.....	.....	.....	.....
Leucoxene	.....	.....	.....	.....	.....	.....	.....	x	.....	.....	.....

	12	13	14	15	16	17	18	19	20	21	22
Quartz	37.9	16.1	22.8	25.3	43.6	38.2	32.0	49.7	28.9	38.3	27.4
Andesine	.....	53.9	.....	57.6	41.3	48.4	45.2	.....	29.2	28.9	.....
Oligoclase	36.1	.....	58.7	.....	.....	.....	.....	22.4	.....	.....	46.2
Albite	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Antiperthite	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.4	.....
Microcline	5.8	.....	4.1	8.7	3.3	.....	.....	16.2	32.5	15.5	19.0
Microcline-microperthite	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.3	.....
Cryptoperthite	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Orthoclase	8.0	10.3	2.3	0.6	.....	3.3	16.1	1.6	1.3	2.2	6.5
Microperthite	6.4	.....	4.1	.....	.....	.....	.....	.....	x	.....	.....
Bictite	0.3	9.8	5.1	5.3	10.1	7.9	4.9	9.4	6.8	4.4	x
Muscovite	2.1	.....	2.6	1.0	0.4	1.7	1.0	0.7	1.0	3.9	0.1
Hornblende	.....	6.8	.....	.....	.....	.....	.....	.....	.....	.....	.....
Augite	.....	0.3	.....	.....	.....	.....	.....	.....	.....	.....	.....
Magnetite	.....	1.3	x	x	x	x	0.3	.....	0.2	x	.....
Apatite	x	1.4	x	0.4	0.2	0.1	0.5	x	x	.....	x
Sphene	.....	.....	.....	x	x	.....	x	.....	.....	x	.....
Zircon	.....	x	x	x	0.1	x	.....	x	.....	x	.....
Monazite	.....	.....	.....	x	x	0.2	.....	x	.....	.....	.....
Garnet	.....	.....	.....	.....	.....	.....	.....	.....	x	.....	.....

TABLE 4.—*Continued*

	12	13	14	15	16	17	18	19	20	21	22
Ilmenite					x						
Rutile											
Allanite											
Tourmaline					x						
Secondary white mica	1.5		0.3	x		x	x	x		x	0.9
Kaolin	x	x	x	x	x	x	x	x	x	x	x
Epidote	1.2				0.1		x			x	
Chlorite	x		0.1	1.0	0.5	x					
Limonite							x			x	x
Hematite											
Calcite	0.7				x						
Zoisite				0.2		0.2				x	
Leucoxene											

	23	24	25	26	27	28	29	30	31	32	33
Quartz	30.1	17.4	29.3	18.5	16.9	21.8	27.9		29.4	31.2	26.7
Andesine	32.1				36.1		22.3				62.0
Oligoclase		39.6	29.6	8.9		14.5			35.2	48.1	
Albite											
Antiperthite				34.7		1.1					
Microcline	25.0	2.9	12.8	27.0	0.8				23.8	3.3	0.5
Microcline-microperthite	8.4	29.7	13.3	9.4		59.1		99.9			
Cryptoperthite											
Orthoclase		0.3	1.3	0.6	37.3		46.4		6.0	6.7	0.5
Microperthite	1.7										
Biotite	1.1	0.2	2.1	x	4.6	0.1	x		3.2	5.4	7.7
Muscovite	1.7		7.5			x	x		1.7	2.1	1.1
Hornblende		5.7		2.1	1.2				1.0	0.8	0.3
Augite											
Magnetite	x	0.4	x		2.6		3.3	x			
Apatite		0.7			0.4	x		x			
Sphene		0.7									
Zircon	x	x	x	x	x	x	x				
Monazite											
Garnet											
Ilmenite						x					
Rutile											
Allanite											
Tourmaline											
Secondary white mica	x		3.0			3.3	x	x			
Kaolin	x	x	x	x	x	x	x	x			
Epidote		x									
Chlorite			1.1								
Limonite		x				x	x				
Hematite								x			
Calcite			x								
Zoisite											
Leucoxene						x					

1. Diorite. Bottom of valley of Bear Creek. SW. ¼ sec. 36, T. 39 N., R. 3 W.
2. Diorite. Same locality as 1.
3. Gneissic tonalite. SW. ¼, SE. ¼ sec. 31, T. 40 N., R. 4 W.
4. Tonalite. S. ½, SW. ¼ sec. 35, T. 39 N., R. 4 W.
5. Leucotonalite. W. Fk. of Potlatch Ck., S. of Beals Butte. SW. ¼ sec. 5, T. 41 N., R. 1 W.
6. Tonalite. Dump of White Cross Mine. SE. ¼ sec. 14, T. 40 N., R. 5 W.
7. Biotite tonalite. Bald Butte Ridge. Hoffman, analyst: Jour. Geol., vol. 40 (1932) p. 643-644.

(*Continued at bottom of next page*)

Contact relations and exomorphism.—Contact relations of plutonic rocks and the Belt formations vary with location and type of rock invaded. In the central and northern parts of the county the type of quartzite determines the nature of the contact. In extremely fine-grained types, such as the gray quartzite, the contact is sharp and follows joint planes, but the contact with the granular quartzite is so gradational that it must arbitrarily be placed within limits that vary within several hundred yards. By increase of feldspar, the quartzite grades into igneous rock. The most extensive example is along the east-west divide between Potlatch drainage and Palouse River and Emerald Creek, in the center of T. 42 N., R. 1 W.

To the south along Potlatch and Little Potlatch drainageways, thin layers of pegmatite and aplite are interbanded with paragneiss and diopside quartzite, forming extensive masses of banded gneiss, described in Table 2. By increase in igneous material, banded gneiss grades into igneous rock containing scattered thin layers of schist, seen along the highway north of Bovill. The belt of banded gneiss, seen in scattered inliers in the basaltic canyons, is 12 miles wide in Latah County and extends, with some interruptions, for another 15 miles to the southeast into Clearwater County where it borders the Idaho batholith (Anderson, 1930, p. 28–29; Pl. 7). In contrast, the Thatuna batholith has only a thin zone of banded gneiss or none at all. Except where banded gneiss occurs, the contact of batholith and schist is sharp. The banded gneiss to the southeast and the increase of metamorphism in that direction indicate a large intrusion, possibly the Idaho batholith, at no great depth beneath the southeast corner of Latah County.

HYPABYSSAL ROCKS

General statement.—At many places the plutonic rocks are bordered by apophyses little different in texture and composition from the main intrusions. A common variation is the almost complete absence of dark mineral. Rocks with the common

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8. Tonalite. Near Troy. SW. ¼ sec. 35, T. 40 N., R. 4 W.
9. Tonalite. White Cross Mine. SE. ¼ sec. 14, T. 40 N., R. 5 W.
10. Leuco-sodaclase-granodiorite-gneiss. Dump of abandoned tunnel. NE. ¼ sec. 14, T. 40 N., R. 5 W.
11. Granodiorite. Same locality as 10.
12. Leucogranodiorite. Same locality as 6.
13. Granodiorite. N of Troy. Near E. ¼ cor., sec. 19, T. 40 N., R. 3 W.
14. Granodiorite. Sec. 27, T. 40 N., R. 3 W.
15. Granodiorite. NW. of Park. SW. ¼, SE. ¼ sec. 3, T. 39 N., R. 1 W
16. Granodiorite. W. ½, SE. ¼ sec. 7, T. 39 N., R. 1 E.
17. Granodiorite. Near center of NE. ¼ sec. 13, T. 39 N., R. 1 W.
18. Granodiorite. Near center of E. ½ sec. 18, T. 40 N., R. 1 E.
19. Quartz adamellite. Bottom of valley of Ruby Ck. SW. ¼ sec. 13, T. 40 N., R. 1 W.
20. Adamellite gneiss. Paradise Ridge.
21. Leucoadamellite. Near S. ¼ cor., sec. 31, T. 40 N., R. 4 W.
22. Leucoadamellite. Sec. 34, T. 40 N., R. 3 W.
23. Leucoadamellite. Along Harvard-Deary road in sec. 36, T. 41 N., R. 3 W.
24. Porphyritic adamellite. N. ½, NW. ¼ sec. 7, T. 39 N., R. 4 W.
25. Leucoadamellite. Same locality as 10.
26. Leucoadamellite. Near Sherwin where highway crosses county line. Sec. 27, T. 42 N., R. 1 E.
27. Adamellite. NW. ¼ sec. 32, T. 41 N., R. 1 E.
28. Leucogranite. NW. ¼, NW. ¼ sec. 34, T. 39 N., R. 5 W.
29. Leucogranite. Near intrusive contact on E. side of Potato Hill.
30. Perthosite. NW. ¼ sec. 2, T. 37 N., R. 4 W.
31. Adamellite. Average of nine specimens listed as 19–27 above. Oligoclase averages $Ab_{78}An_{22}$.
32. Granodiorite. Average of nine specimens listed as 10–18 above. Plagioclase is sodic andesine in most specimens but averages $Ab_{75}An_{25}$.
33. Tonalite. Average of seven specimens listed as 3–9 above. Andesine averages $Ab_{62}An_{38}$.

texture and structure of hypabyssal rocks include granodiorite porphyry, gradational to adamellite porphyry, granite porphyry, and diorite porphyry. Pegmatites, aplites, and lamprophyres are common.

Granodiorite porphyry and related rocks.—Porphyritic dikes are most abundant east and south of Bovill. Two localities have special textural varieties: (1) the bottom of Dry Creek in sec. 11, T. 39 N., R. 3 W., more than a mile above its mouth; (2) Corral Creek on the northwest side of Cherry Knob. A few dikes occur near the Hatter Creek road south of Princeton. Microscopically most of the rocks are granodiorite porphyry. Megascopically a typical rock is medium gray but may be greenish gray. The groundmass is fine to stony, and phenocrysts generally are 1 to 2 mm. The most common phenocrysts are biotite and light laths of plagioclase, but hornblende occurs at places.

Compositions are given in Table 5 (Nos. 1 and 2). The rock from Dry Creek (No. 1) is typical of most of the granodiorite porphyry in that phenocrysts form a large part of the rock, and the groundmass is very fine (Pl. 4, fig. 3). Table 6 gives the proportions of the principal minerals in phenocrysts and groundmass. In the rock from Corral Creek phenocrysts are few, and their diameters are only about three times those of crystals in the groundmass.

A rare example of granodiorite porphyry with groundmass too fine to determine occurs on a tributary of Potlatch Creek a mile east of Cornell. The rock is white and contains less than 5 per cent dark minerals. Light cream-colored feldspar phenocrysts are in a groundmass of feldspar microlites cemented by quartz grains 0.1 mm. in diameter. The principal minerals are oligoclase ($Ab_{83}An_{17}$), quartz, orthoclase, and microcline. Magnetite is accessory, and zoisite and white mica are secondary. A partial chemical analysis by Charles Bentley, Analyst of the Mining Experiment Station, South Dakota State School of Mines, shows: 77.24 per cent SiO_2, 1.06 per cent Fe_2O_3, 13.38 per cent Al_2O_3, 0.40 per cent CaO, 0.56 per cent MgO, 3.26 per cent K_2O, 3.94 per cent Na_2O, 0.90 per cent loss on ignition. The norm is 39.9 per cent quartz, 35.5 per cent plagioclase ($Ab_{90}An_{10}$), 19.5 per cent potash feldspar, 2.5 per cent mafic minerals.

Granodiorite porphyry grades through light-gray adamellite porphyry into cream and chalk-white granite porphyry resembling extrusive rock and seldom containing more than 3 or 4 per cent of dark mineral.

Aplites and pegmatites.—The aplites have typical texture, but some grade toward the coarser granitic rocks that form many apophyses of the batholith. The chief minerals are quartz, potash feldspar (microcline, orthoclase, or microperthite), and plagioclase, usually oligoclase. Plagioclase usually exceeds 5 per cent. Small amounts of biotite and muscovite are common, and magnetite, apatite, zircon, and garnet are accessory. Most of the specimens are granite aplite, but small dikes of diorite aplite (No. 3, Table 5) were found three-quarters of a mile south of Bovill.

Descriptions of the granite pegmatites near Avon have been given by Shannon (1922), Sterrett (1923), Anderson and Piper (1924), Anderson (1933), Campbell (1939), Scheid and Allen (1940), and Forrester (1942). Simple pegmatites without the rare minerals found at Avon are abundant in all parts of the Thatuna batholith and at many places just outside its margin.

TABLE 5.—*Volumetric modes of hypabyssal rocks of Latah County*

	1	2	3	4	5
Quartz	19.1	11.7	.....	4.2	8.2
Orthoclase	16.5	24.6	1.4	.....	.....
Albite	.....	4.0	.....	60.9	.....
Oligoclase	.....	.....	97.1	.....	.....
Andesine	51.5	47.9	.....	.....	.....
Labradorite	.....	.....	.....	.....	49.6
Biotite	11.4	9.6	.....	x	.....
Hornblende	1.5	0.7	x	4.2	0.1
Augite	.....	x	1.5	.....	4.5
Magnetite	x	1.0	.....	2.7	3.6
Apatite	x	0.2	x	0.8	2.2
Zircon	x	x	.....	.....	.....
Pyrite	x	.....	.....	.....	.....
Chlorite	x	x	.....	20.4	15.6
Epidote	.....	.....	.....	6.4	2.3
Kaolin	x	x	x	x	x
Secondary white mica	.....	x	.....	0.3	0.1
Calcite	.....	x	.....	x	0.4
Limonite	x	x	.....	x	.....
Hematite	.....	.....	.....	x	.....
Remainder	.....	.....	.....	.....	13.4*

* Includes 12.3 per cent of microcryptocrystalline spherulitic material probably consisting of quartz and an alkali feldspar.

1. Granodiorite porphyry from Dry Creek, near center of sec. 11, T. 39 N., R. 3 W.
2. Granodiorite porphyry from Corral Creek, in N. ½ sec. 1, T. 40 N., R. 2 W.
3. Leucodiorite aplite, near Bovill, in NE. ¼, NE. ¼, sec. 1, T. 40 N., R. 1 W.
4. Lamprophyre, Bovill-Elk River highway, near center of sec. 18, T. 40 N., R. 1 E.
5. Lamprophyre, just west of county line near Ruby Creek Mine.

TABLE 6.—*Mineralogical composition of granodiorite porphyry from Dry Creek*

Mineral	Phenocrysts	Groundmass	Total
Quartz	1.2	17.9	19.1
Andesine	49.7	1.8	51.5
Orthoclase	0.0	16.5	16.5
Biotite	4.0	7.4	11.4
Hornblende	1.5	0.0	1.5
Total	56.4	43.6	100.0

Lamprophyres.—Lamprophyre dikes are numerous in the southeast part of the county. The fresh rocks are dark gray to dark green. Many dikes are not porphyritic, or, if they are, the phenocrysts are plagioclase instead of dark mineral. The microscopic texture resembles diabasic, but plagioclase laths have ragged outlines (Pl. 4, fig. 4). The average grain size is between 0.5 and 0.75 mm.

The composition is closest to spessartite, but few dikes are typical spessartite. The principal mineral is plagioclase—albite in some rocks and labradorite in others, but andesine in most. The chief dark mineral is brown hornblende or microscopically colorless augite, altered to chlorite and epidote. Secondary calcite is common, and magnetite and apatite are abundant. The quartz content is high enough to place most of the dikes in the tonalite family, and the content of dark mineral is a little less than normal in lamprophyre (Nos. 4 and 5, Table 5). Such rocks might be termed quartz spessartite. Specimens 4 and 5 represent extremes. Albite in No. 4 has the composition $Ab_{95}An_5$, and plagioclase in No. 5 ranges from andesine ($Ab_{57}An_{43}$) to labradorite ($Ab_{40}An_{60}$) within single crystals with average about $Ab_{47}An_{53}$.

GOLD HILL STOCK

General statement.—The syenite and related quartz-poor rocks of Gold Hill (Stewart, 1914; Faick, 1937), north of Princeton, differ sufficiently to deserve separate discussion. The stock occupies $6\frac{1}{2}$ square miles, and two small outliers occur in the bottoms of Hoteling and Gold creeks. The porphyritic border phase crops out in a railroad cut east of Princeton 2 miles south of the main contact.

The main intrusion is variable. The dominant type appears to be syenite, but considerable masses of monzonite and syenodiorite occur. Among the border rocks adamellite is common, but much granodiorite is found, and also syenite, albite syenosyenodiorite, and tonalite. Many dikes of adamellite porphyry occur, and aplite and pyroxenite are the most common diaschistic rocks. Pyroxenite grades into pegmatitic dark syenite and granite on one hand and into dunite and magnetitite on the other.

Description and origin of hornblende syenite.—Many outcrops along roads at the west side of Gold Hill show transition to the border phase. The central intrusive of typical hornblende syenite and subordinate hornblende monzonite and hornblende syenodiorite is accessible by foot trails.

The hornblende syenite and related plutonic rocks are gray. The texture is equigranular, transitional to porphyritic. The most abundant minerals are irregular to stubby prisms of light-gray potash feldspar and white to cream-colored plagioclase, and dark-green hornblende. Most grains are between 1 mm. and 2 mm., but hornblende is up to 5 mm. Phenocrysts are pink to gray microcline up to 2 cm. Small crystals of sphene and of light-green pyroxene are abundant.

Microscopically (Pl. 4, fig. 5) potash feldspar generally exceeds plagioclase 2:1. No. 1 in Table 7 is a Rosiwal analysis. Plagioclase is sodic oligoclase, $Ab_{90}An_{10}$ to $Ab_{80}An_{20}$, but Faick reports andesine also. Augite is faintly green suggesting presence of the aegirite molecule. Magnetite, sphene, and apatite are more abundant and in larger crystals than in the Thatuna batholith, while zircon is rarer.

Allowing for overlap, the order of crystallization is: accessory minerals, augite, hornblende, plagioclase, potash feldspar, and quartz. Automorphic crystals of sphene which form inclusions and cut boundaries of other minerals may be late replacements.

Microcline and, to a lesser extent, quartz have "replaced" plagioclase about the margins of crystals. Faick (1937, p. 14–18) concluded that the replacements have

converted an original quartz diorite (found at places in the border of the stock) into the present syenite. The writer has estimated that the plagioclase removed probably did not exceed 20 per cent of that now present. Substitution of the limited

TABLE 7.—*Volumetric modes of rocks from Gold Hill*

	1	2	3	4
Quartz	0.6	12.9	10	.....
Orthoclase	6.4	4.7	.....	.....
Microperthite	2.0	6.7	.....	.....
Microcline	7.7	4.5	.....	.....
Microcline-microperthite	35.0	21.9	.....	.....
Albite	.....	.....	.....	1.7
Oligoclase	26.5	.....	.....	.....
Andesine	.....	38.2	65	.....
Hornblende	11.4	4.9	15	1.2
Augite	5.4	1.7	5	74.3
Biotite	.....	x	.....	7.3
Magnetite	2.0	2.8	.....	.....
Ilmenite	.....	.....	.....	10.7
Sphene	1.5	1.0	.....	1.6
Apatite	x	0.5	.....	3.2
Zircon	x	0.1	.....	.....
Epidote	1.4	.....	.....	0.1
Secondary white mica	0.1	x	.....	.....
Kaolin	x	x	.....	x
Carbonate	.....	x	.....	x
Chlorite	.....	x	.....	.....
Remainder	.....	.....	5*	.....

* Includes microcline, orthoclase, and accessory minerals.

1. Hornblende syenite from Gold Hill.
2. Porphyritic adamellite from the southern border of Gold Hill.
3. Quartz diorite (tonalite) from margin of Gold Hill. Faick (1937, p. 14), analyst.
4. Biotite-ilmenite pyroxenite from Gold Bug Mine.

amount of plagioclase apparently removed would not be enough to change the present rock from syenite or monzonite. As for the original rock having been quartz diorite, the writer has found no evidence of replacement of quartz by microcline, but rather has found quartz embaying plagioclase.

Porphyritic adamellite and other border rocks.—Most of the border is porphyritic and variable in appearance. One of the most common rocks, porphyritic adamellite, is exposed on the west and south sides of Gold Hill, for example, in the railroad cut east of Princeton. Other types, including granodiorite, albite syenodiorite, quartz diorite, and porphyritic syenite occur in the mines at the headwaters of Jerome Creek on the east side of Gold Hill, at the Carrico tunnels, and along the tributaries of Gold Creek on the west side. Some of the rocks are large dikes but have plutonic texture. Table 7, No. 2, is a Rosiwal mode of typical porphyritic adamellite.

Quartz diorite (Table 7, No. 3) has been described by Faick (1937, p. 14–15). It resembles syenite but contains quartz. It is porphyritic in part and locally is granodiorite. Albite syenodiorite, at the Gold Bug Mine, is light pink and contains segregations, up to more than an inch across, of green hornblende.

Description and origin of ultrabasic rocks.—Ultrabasic dikes occur along the tributaries of Jerome Creek and near the head of Hoteling Creek. There are several distinct types—pyroxenite, dark syenitic pegmatite, magnetite dunite, and magnetitite—but these are gradational. Dark-green, fine- to medium-grained pyroxenite is the most common. It is equigranular but may have phenocrysts of pyroxene up to 3 mm. long and so resemble lamprophyre. Typical pyroxenite (Table 7, No. 4) is dominantly augite, colorless to light green suggestive of aegerine. At places the color suggests presence of titanium. Microcline may take the place of all or part of the albite. Ilmenite is rimmed with sphene (Pl. 4, fig. 6).

Pyroxenite grades to dark syenite, which at the Gold Bug Mine is pegmatitic and contains medium-green augite, black biotite partly altered to golden brown, and medium-gray feldspar, all generally measuring between 2 and 4 cm. but at places more than 12 cm. Magnetite, sphene, pyrite, and chalcopyrite grains are not larger than $\frac{1}{4}$ cm. Feldspar content may approach 50 per cent. Microcline exceeds albite in the rocks with a high percentage of feldspar but in other specimens albite may be the only feldspar. At places the pegmatite contains enough quartz to be granite.

Many specimens of pyroxenite at the head of Hoteling Creek contain exceptionally abundant magnetite, and some specimens classed as magnetite dunite contain olivine instead of augite. The texture of dunite is irregular, with olivine concentrated in patches and streaks through magnetite. Dunite grades into magnetitite which is never entirely free of olivine. No gradation between pyroxenite and dunite was found. Fresh specimens are only on prospect dumps, so field relations were not determined.

Order of crystallization in pyroxenite and pegmatite is: (1) augite, (2) apatite, (3) biotite and hornblende, (4) ilmenite and magnetite partly simultaneous with biotite and hornblende and partly later, (5) sphene, (6) albite, microcline, and quartz. Biotite and hornblende replace augite, and microcline replaces biotite extensively but augite only slightly.

On Hoteling Creek ultrabasic rocks occupy a linear zone about a quarter of a mile long three-quarters of a mile inside the stock. This may indicate that they were intruded along fractures cutting the stock.

Faick (1937, p. 13) suggested that the ultrabasic rocks are older than the syenite and that the pegmatite resulted from metamorphism of the ultrabasic rocks by the syenite. Instead, it appears that the pegmatite is a primary phase of a basic intrusion. As such the pegmatite is the product of the final magmatic stage of an intermediate magma of which the pyroxenite and related rocks were a differentiated residual. This hypothesis is supported by the fact that certain amounts of the pegmatitic minerals are found in pyroxenite in textural relations suggesting primary magmatic minerals. Doubtless hornblende, biotite, and feldspar in the pegmatite made way for themselves *in part* by replacement, but apparently this was a result of late magmatic action accompanying intrusion of pyroxenite rather than the effect of emanations from a younger syenitic intrusion.

The igneous rocks are cut by veins of pyrite, tetrahedrite, magnetite, specularite, chalcopyrite, gold, quartz, barite, and ankerite.

AGE AND CORRELATION OF INTRUSIVE ROCKS

Nothing new concerning the age of the intrusive rocks can be learned in Latah County. Those who have studied the Thatuna batholith agree that it should be correlated with the Idaho batholith, which, according to Ross (1928), is late Jurassic or early Cretaceous.

The relative ages of the various types of hypabyssal rocks were not determined certainly. One example of transection of lamprophyre by granite porphyry was seen. Close association of aplites and pegmatites with the batholith indicates genetic relationship. The sporadic occurrence of granodiorite porphyry and lamprophyre dikes suggests that they may differ in age from the batholith. However, the dikes do not extend far outside the area of plutonic intrusion and so probably are the same age. The possibility that some of the dikes might be early Tertiary (Anderson, 1940) or Miocene (Ross, 1934) should not be overlooked.

In view of its entirely different characteristics the Gold Hill stock may be of distinctly different age from the Thatuna batholith, as was recently suggested by Anderson (1941, p. 655).

TERTIARY EXTRUSIVE ROCKS

COLUMBIA RIVER BASALT

General statement.—The name "Columbia River basalt" is applied to Tertiary extrusive rocks in northern Idaho and bordering parts of Washington. General descriptions are given in reports of reconnaissance surveys by Russell (1901, p. 28–35), Lindgren (1904, p. 24–25), and Anderson (1930, p. 25–26). Except for brief descriptions by Johnson and Myrene (1929, p. 13) and by Goodspeed (Wilson and Goodspeed, 1934, p. 81–82) the Latah County basalts have not been studied microscopically.

Approximately 397 square miles of Latah County is underlain by lava, and most of it represents projections of the Columbia Plateau into old valleys in pre-Tertiary rocks. The top of the basalt slopes about 10 feet per mile from an elevation of 2950 or 3000 feet along the southeast margin of the county to about 2900 feet near Linden, Park, Deary, and Bovill, and to 2650 feet west of Moscow and 2575 feet west of Potlatch.

Thickness.—Near Juliaetta, Potlatch River has cut about 1700 feet below the plateau without penetrating the bottom of the lava. Of this, 250 to 350 feet represents the Latah lake beds. Possibly the maximum thickness of basalt is beneath Genesee, but it is not likely to exceed 2000 feet, including Latah sediments. The thickness of individual flows varies from a few feet to 200 feet.

Megascopic features.—The typical basalt is dark gray but weathers rusty brown. Fresh surfaces generally are lusterless and slightly rough. Usually the basalt is so fine-grained that, except for small prisms of plagioclase, minerals cannot be distinguished. Rarely the rocks are porphyritic with widely spaced phenocrysts of glassy plagioclase up to 5 mm. long.

Microscopic features.—Microscopic study of 20 specimens shows more uniformity

than indicated by hand specimens. The texture generally is intergranular to intersertal but is pilotaxitic where the rock is finer-grained and contains fewer dark minerals. The average grain varies from 1.2 mm. to 0.15 mm.

Three-quarters of the specimens contain olivine up to about 25 per cent but averaging less than 10 per cent. The other main variation is that some specimens are rich in magnetite and augite, which total 75 per cent in one case. The volumetric Rosiwal mode of a typical specimen (Pl. 5, figs. 3, 4) of olivine basalt is: 43.8 per cent labradorite, 28.6 per cent augite, 4.0 per cent magnetite, 3.4 per cent olivine, 1.8 per cent apatite, 17.3 per cent glass, 1.2 per cent chlorophaeite, and a small amount of carbonate. The rock is from the bottom of Little Potlatch Canyon in SW. $\frac{1}{4}$, SW. $\frac{1}{4}$ sec. 11, T. 38 N., R. 4 W., at an elevation of 2180 feet. Additional minerals in other specimens include titaniferous magnetite or ilmenite, iddingsite, chlorite, serpentine, limonite, and leucoxene. The average composition of labradorite in all sections is $Ab_{42}An_{58}$, which is close to Ab_3An_4 given by Calkins (1902, p. 161) for Columbia River lavas in John Day Basin.

Brown glass occurs except in rocks poor in dark minerals. It is light where free of crystallites or almost opaque where crowded with them. In the specimen reported above, the index of refraction of glass was 1.508 ± 0.004. George (1924) reported the average index of basaltic glass to be 1.575. According to his curves a glass with index 1.508 should have a composition similar to granodiorite. This result suggests the extent of magmatic differentiation when 83 per cent of the basaltic magma had crystallized.

Tuff.—Beds of tuff between or beneath basalt flows are common. The unaltered material varies from black to white. The microscope shows highly altered glass and much foreign quartz, feldspar, and mica. The most characteristic feature is alteration to pink or brick red. The alteration extends throughout the mass of tuff but does not affect basalt flows above and below. An instructive example is on Dry Creek about $1\frac{3}{4}$ miles south of the Troy-Deary highway, where a bed of tuff 23 feet thick rests on granite and is overlain by unaltered basalt. The lower 8 feet of tuff is white, while the upper 15 feet is red. Whatever the cause, the color difference must have existed before extrusion of the basalt. This point is important in connection with the origin of certain basaltic clays described later.

Age.—The age of at least part of the Columbia River basalt in Latah County is fixed by its relationship to the Latah beds which occur at more than one horizon between flows. These beds have been assigned to the middle or upper Miocene (Knowlton, 1926; Berry, 1929; Brown, 1936), but Berry (1934, p. 101) has suggested that in this area deposition may have extended into the Pliocene.

YOUNGER LAVA

General relationships.—Lava flows much different from typical Columbia River basalt occur north and south of the Thatuna Hills. The rocks underlie 32 square miles, mostly in seven areas in Palouse Valley. An eighth occurrence is on the southeast margin of the Thatuna Hills, between Randall Flat School and Troy.

Contrary to the distribution of the Columbia River basalt, the younger lavas do not rise to a constant elevation on the hills. The flows are found at elevations up to 3050 feet, while the top of the Columbia River basalt is at 2800 feet on the east and

2650 feet on the west. The lowest elevation at which younger basalt was seen is about 2500 feet near Potlatch, where the top of the youngest Columbia River flow is at 2650 feet. The younger basalt is covered with loess, and the Palouse River and tributaries have cut valleys through loess and into the basalt to depths as great as 100 feet.

Loess covers the contact between the two lavas, but the relationships indicate that the latest Columbia River flows were cut by valleys 150 feet deep before extrusion of the younger lava. The constant upper level of Columbia River basalt may indicate extrusion from distant vents to the west, while the variable upper level of the younger flows may indicate local eruptions.

Possibly the thickness at one place is no more than 100 feet. Flows probably originated at a number of vents and moved down hillsides and valleys through small distances compared with those through which individual Columbia River flows may be traced.

Cinder cone.—Kirkham (1927, p. 4, 5) and Scheid (1937) described the small cinder cone half a mile east of Princeton but did not mention its association with lavas distinct from the Columbia River basalt. The cone is several feet high, and its top is surrounded by a basalt flow. Beneath the flow for a few hundred feet laterally are tuff and scoria inclined away from the vent. The fragmental material is brown, red, and pink, but the basalt is black and shows the features typical of the younger flows. The vent is at a low elevation compared to most of the younger lava. No fragmental material was found elsewhere with the younger lava, nor have other vents been found.

Megascopic features.—Columnar jointing is not so conspicuous as in Columbia River flows, nor is it so persistent vertically. Cross joints are more closely spaced than in Columbia River lavas and divide the rock into curved plates 1 to 4 inches thick and 2 to 3 feet in diameter. There is no enlargement of joints by weathering as in the Columbia River basalt, nor do ball-and-socket joints occur.

The younger flows weather to characteristic chocolate color, but the fresh rock is black, with an almost satiny luster, brilliant when compared with a dull specimen of Columbia River basalt. Glassy phenocrysts of colorless to amber labradorite are typical. These generally are about 5 mm. long and 2 mm. in diameter and may be sparse or may compose 10 per cent of the rock. Rare phenocrysts of olivine are up to 3 mm. in diameter.

Microscopic features.—Texturally the younger lava is quite different from Columbia River basalt (Pl. 5, figs. 2–4). The younger flows are porphyritic with groundmass fine-granular to intergranular. Two sizes of plagioclase phenocrysts are about 5 mm. and up to 1 mm. in length, respectively. The former have sharp edges and corners, while the latter are ragged (Pl. 5, fig. 2). Olivine forms phenocrysts and also is in the groundmass.

Rosiwal analysis of a typical specimen from sec. 20, T. 42 N., R. 4 W., along Crane Creek, shows: 50.9 per cent plagioclase, 21.6 per cent pyroxene, 12.3 per cent magnetite, 7.7 per cent olivine, 1.5 per cent apatite, 6.0 per cent chlorite. This is not essentially different from the composition of Columbia River basalt, except that glass is typically absent. The large plagioclase phenocrysts are about $Ab_{45}An_{55}$, while

the small phenocrysts and the feldspar in the groundmass range from sodic labradorite to calcic andesine and probably average a little more sodic than $Ab_{50}An_{50}$. Pyroxene forms stubby prisms about 0.05 mm. long, frequently in clusters. Generally it is colorless but in a few specimens approaches the brown angular augite of the Columbia River basalt. Apatite crystals, frequently hairlike, are elongated up to 0.4 mm. One section contains biotite and basaltic hornblende, both much resorbed. Olivine is universal, slightly altered to chlorite. Part of the chlorite, frequently rather abundant, probably has formed from other ferromagnesian minerals. The rock should be classed as basalt rather than andesite.

Age.—Field relations indicate that in part the younger lavas filled valleys eroded in the upper flows of Columbia River basalt. Although the bulk of Columbia River basalt is middle or upper Miocene, the upper flows may be Pliocene. If so, the "younger lava" also is Pliocene or younger. It is covered by Pleistocene loess.

ORIGIN OF CLAY DEPOSITS

GENERAL STATEMENT

Clay deposits constitute Latah County's most important economic resource. Several investigators (Soper, 1918; Skeels and Wilson, 1920; Wilson, Bennett, and Heath, 1923; Hite, 1930; Tullis and Laney, 1933; Wilson and Goodspeed, 1934; Scheid, 1940a) have reported, but Plate 6 shows several deposits previously unnoticed. Because of difference of opinion, a brief summary of geologic conditions is given, together with observations additional to those in the writer's earlier report (Tullis and Laney, 1933).

There are three types of deposits: (1) residual from granitic and metamorphic rocks, (2) transported, derived from the first type, and (3) basaltic. The second type will not be discussed since its origin is clear. Goodspeed believes that the granitic clay is hydrothermal and that the basaltic clay results from weathering. Both views are opposed to those of the writer. Scheid believes that certain of the basaltic clays result from weathering.

GRANITIC CLAY

Geologic conditions.—The pre-Miocene rocks, excepting some of the fine-grained metamorphic rocks and the Permian(?) volcanics, are badly weathered in most outcrops. However, this widespread alteration is superficial when compared with changes found at places in the granitic and metamorphic rocks. Where indicated on the geologic map (Pl. 6) at a number of points along the south margin of the Thatuna batholith and about stocks to the southeast, the igneous and, at a few places, the metamorphic rocks are completely altered to clay with no remnants of original fresh minerals except quartz, muscovite, and some accessories. Feldspar and biotite are completely altered to kaolin, and the product is pure white except where overlain by basalt. One deposit underlies about a square mile, and in some cases drilling 100 feet has not revealed the bottom. There are no special channels of alteration.

Two rules govern the distribution of the residual clay: (1) It is associated with margins of basalt flows against the hills of older rocks and is found beneath the margins of the flows, or not far beyond and above. If the clay is a few miles beyond

the edge of the basalt on the uphill side, the deposits are not far above the basalt. (2) In all such places the clay is restricted to flat divides.

Wilson and Goodspeed (1934, p. 65) believe that the curved line along which the clay deposits are found "indicates the plane of contact between the granitic intrusives and the older Algonkian rocks, where the opportunities for alteration and kaolinization were greatest." This statement is to be considered in the light of Goodspeed's belief that the clay has been formed by hydrothermal solutions, in the closing stages of intrusive activity. His geologic sketch map shows the residual deposits, with one exception, located near the margins of the basalt flows, as the writer indicated above, so he must have believed that the contact between granodiorite and metamorphic rocks is buried beneath the basalt not far from its margin. All but 3 or 4 of the 14 deposits shown on Goodspeed's map are transported clays that have been moved downhill toward the supposed position of the intrusive contact, through distances in some cases probably a mile or more from the original residual deposits. The writer has found that, of the residual deposits shown by Goodspeed, Joel is near an intrusive contact and the others are from 1 to 3 miles inside the intrusion. On the south side of the Thatuna Hills the basalt overlaps onto the granitic rocks, and residual clay deposits are large and numerous, while on the north side the basalt does not overlap the granitic rocks at most places, and residual clay deposits are absent.

The relationships of the transported clays offer evidence of the time of formation of the parent residual clays. The transported clays generally occur within the area of the basaltic plateau, mostly not more than a mile from its margin, and either on top of or immediately beneath the youngest flow. The residual clays which were the source of the transported bodies must have been formed before extrusion of the basalt. At the Johansen pit a thin, unaltered flow overlies granodiorite almost completely altered to an unknown depth.

Mineralogy.—The clay preserves the texture of the original rock. Microscopic examination shows the principal new mineral to be kaolinite (Tullis and Laney, 1933). Feldspar and biotite alter to kaolinite almost completely, but muscovite alters only locally, although few flakes are entirely free of alteration as shown by marked decrease in higher indices of refraction. The largest kaolinite crystals probably come from biotite (Pl. 5, fig. 5). Micaceous minerals resembling muscovite, but with lower birefringence, and an isotropic mineral, probably halloysite, form intermediate stages. Microscopic study of samples from a vertical range in the Johansen pit indicates that biotite and muscovite flakes are fresher with depth. Accessory minerals in the clay are the same as in the original rock and seem to be present in the same amounts.

Goodspeed (Wilson and Goodspeed, 1934, p. 65, 79) reports kaolinite as the dominant mineral but also emphasizes the presence of a mineral he believes to be dickite, for which he does not give complete data. The writer has rechecked optical properties of the minerals in his own samples but has found none conforming to dickite.

Origin.—Goodspeed's belief that the clay results from hydrothermal alteration seems to be based on the following points: (1) the presence of a certain amount of dickite; (2) the occurrence of minerals such as epidote, cyanite, and tourmaline believed to have resulted from igneous metamorphism; (3) the irregular distribution

of the completely kaolinized rock; and (4) the occurrence of the deposits along a curved line believed to approximate the contact of the igneous intrusion.

If dickite is present, hydrothermal action must be considered. The optical properties of the mineral should be more completely investigated. It is agreed that kaolinite is the chief mineral. The accessory minerals attributed to hydrothermal action also are present in the unaltered rock, apparently in the same amounts as in the clay. The irregularity of clay distribution is believed by the writer to result from erosion of more extensive deposits with preservation on certain flat divides where basalt has protected the clay by maintaining a low gradient. Detailed mapping on both sides of the Thatuna Hills has shown that the exposed clay is not distributed along the intrusive contact but rather is related to the protective margin of the basaltic plateau. In addition to these answers to Goodspeed's arguments, the writer's belief that the clay deposits result from weathering is based on the following points:

(1) The clay is homogeneous over areas up to a square mile.

(2) There is no evidence of channels followed by hydrothermal solutions.

(3) The principal clay mineral is kaolinite, which is believed to be formed in abundance only by weathering (Ross and Kerr, p. 174–176).

(4) Alteration of biotite and muscovite apparently decreases at depth.

BASALTIC CLAY

At a number of places basalt has been altered to clay. Of 12 localities visited, 10 exhibit light gray color. Exposures show only cross sections, and little can be learned about areal distribution. The widths vary from 50 to 300 feet. Laterally the clay grades from soft, friable material into solid basalt. Detailed mapping shows the clays are in the top as well as in the older flows.

The clay near Troy shows genetic relationship. The best known exposure is in the NE. $\frac{1}{4}$ sec. 18, T. 39 N., R. 3 W., about half a mile below the Troy-Deary highway. The outcrop extends along the creek for 200 feet, and the clay grades sharply into unaltered basalt at both ends. The clay is wider at the bottom. It has lost all traces of basaltic jointing and is marked by solution channels. Bleaching is at a maximum at the center of the deposit. In the stream bed is an unknown thickness of altered pink tuff. The slope above the outcrop is covered with basaltic talus and stream boulders, but on the plateau, a short distance from the valley and about 300 feet above the outcrop, more clay occurs. The line between the exposures strikes about N. 50 W., and on the extension of the line in that direction are four additional clay outcrops within $1\frac{3}{4}$ miles. The two most distant are in railroad cuts and a highway cut west of Troy. Fresh basalt intervenes between clay exposures.

The late Dr. F. B. Laney believed that the clay was formed by hydrothermal action during the period of extrusive activity. The writer believed that the evidence supports this idea and gave the matter little thought until Goodspeed (Wilson and Goodspeed, 1934, p. 66–67) concluded that the clay was formed by weathering before it was covered by later flows. He suggests that lack of continuity results from younger flows filling valleys in the weathered basalt. Scheid (1940a, p. 9, 46) believes that the numerous deposits of gray clay result from weathering but agrees

(personal communication, April 22, 1941) that the deposit near Troy is of hydrothermal origin. Evidence supporting the hypothesis of hydrothermal origin is:

(1) Clay occurs not only in the older flows, as believed by Goodspeed, but also in the younger.

(2) Clay occurs in limited areas and grades laterally into fresh basalt at the same elevation. This is true both of buried and surface flows. Goodspeed's hypothesis that fresh flows filled valleys cut in weathered basalt does not explain gradational contacts or the occurrence of clay in the youngest Columbia River flows in the region.

(3) The altered clay at Troy is in a vertical range of 300 feet and appears to be localized along a vertical plane cutting more than one flow.

(4) In spite of considerable iron in the clay, it generally is gray and not red as would be expected if the deposits had been formed by surface waters carrying oxygen. In contrast, certain tuff beds are red apparently from oxidation at time of deposition or at least before extrusion of overlying flows.

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South Dakota School of Mines and Technology, Rapid City, S. D.

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EXPLANATION OF PLATES 4 AND 5

PLATE 4.—PHOTOMICROGRAPHS OF INTRUSIVE ROCKS

Figure

1. Granodiorite. Minerals are quartz, andesine, microcline, and biotite. Microcline is the latest to crystallize and in part has formed at expense of earlier minerals. Specimen 16, Table 4. Crossed nicols, ×23.
2. Perthosite. Specimen 30, Table 4. Crossed nicols, ×23.
3. Granodiorite porphyry from Dry Creek. Phenocrysts of plagioclase, quartz, magnetite, and biotite in a groundmass of quartz, biotite, and plagioclase. Specimen 1, Table 5. Ordinary light, ×23.
4. Quartz spessartite. Minerals are labradorite, augite, chlorite, quartz, epidote, and magnetite. Specimen 5, Table 5. Ordinary light, ×23.
5. Hornblende syenite from Gold Hill. Contains microcline, microcline-microperthite, plagioclase, hornblende, augite, and sphene. Specimen 1, Table 7. Ordinary light, ×23.
6. Biotite-ilmenite pyroxenite from Gold Hill. A rim of sphene may be seen about the ilmenite. Specimen 4, Table 7. Ordinary light, ×23.

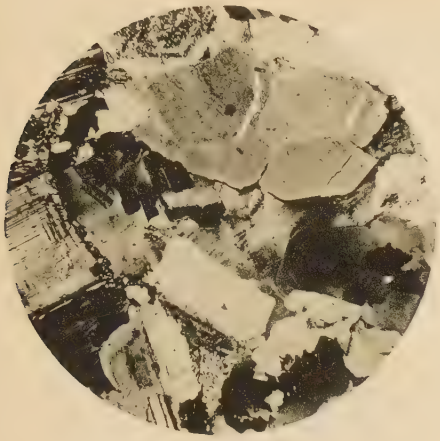


FIGURE 1

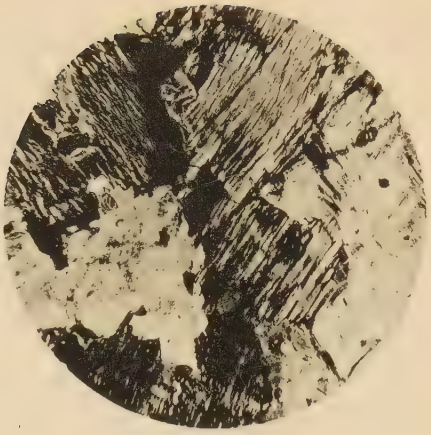


FIGURE 2

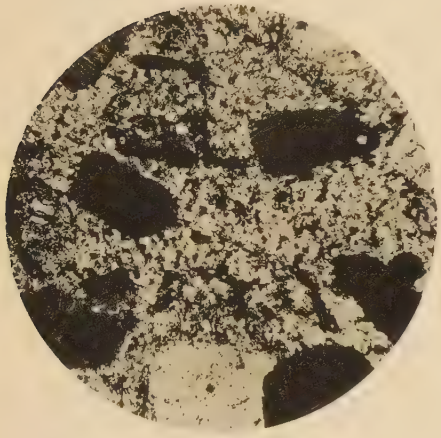


FIGURE 3

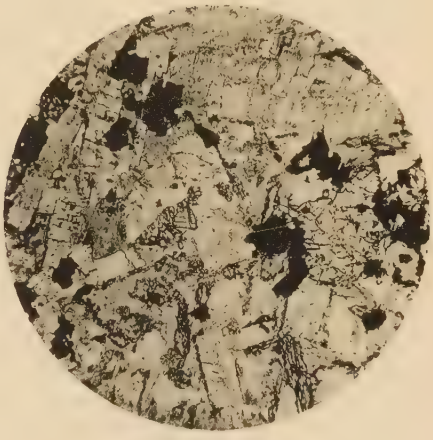


FIGURE 4

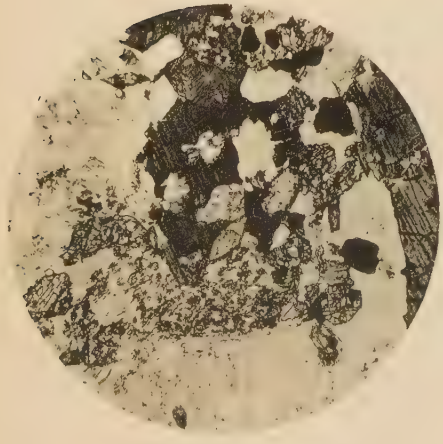


FIGURE 5

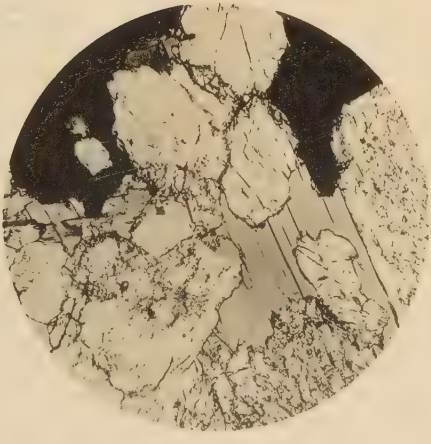


FIGURE 6

PHOTOMICROGRAPHS OF INTRUSIVE ROCKS

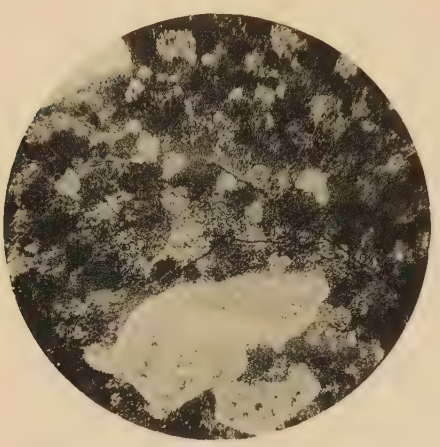


FIGURE 1

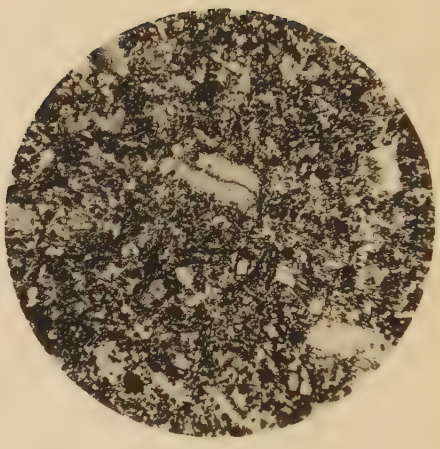


FIGURE 2

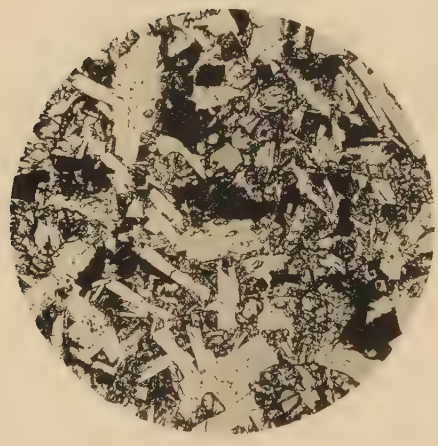


FIGURE 3

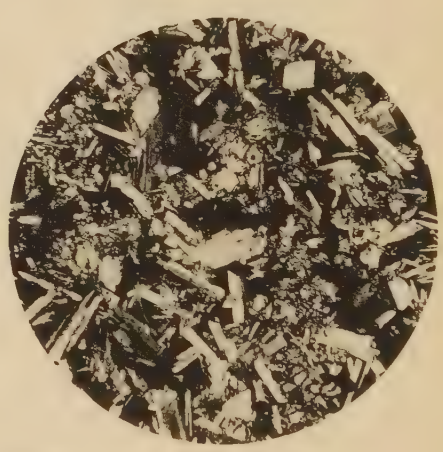


FIGURE 4

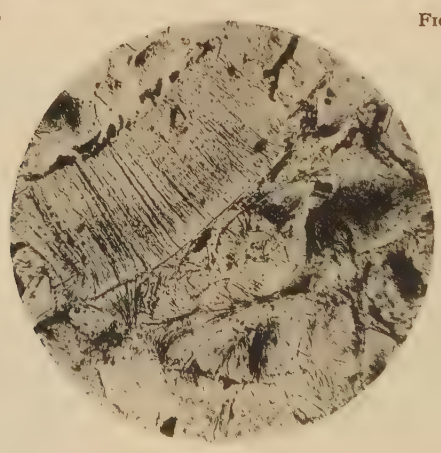


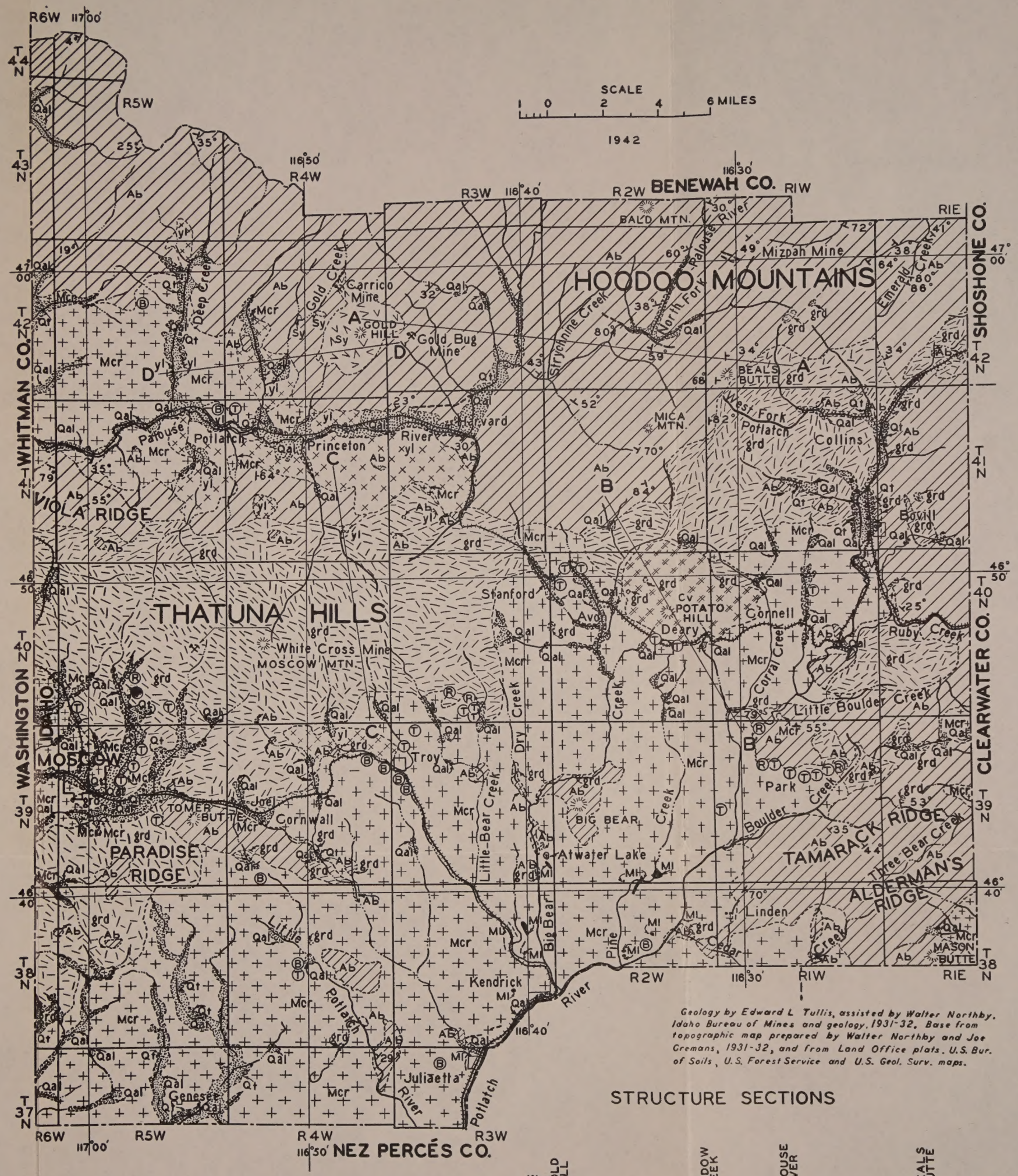
FIGURE 5

PHOTOMICROGRAPHS OF EXTRUSIVE ROCKS AND OF RESIDUAL CLAY

PLATE 5.—PHOTOMICROGRAPHS OF EXTRUSIVE ROCKS AND OF RESIDUAL CLAY

Figure

1. Dark rhyodacite from ridge northwest of Potato Hill. The mottled groundmass has micropoikilitic texture, the detail of which cannot be seen at this magnification. Note partially resorbed phenocrysts of oligoclase. Crossed nicols, ×23.
2. Younger lava from Crane Creek. Crossed nicols, ×23.
3. Columbia River basalt. Typical olivine basalt. Ordinary light, ×23.
4. Same as Figure 3, crossed nicols.
5. Kaolinite in residual granitic clay. Kaolinite is forming from biotite, dark remnants of which are visible. Lower nicol only, ×76.



EXPLANATION

SEDIMENTARY ROCKS

- Qal — Alluvium
- Qt — Terrace Deposits (UPPER(?) PLEISTOCENE)
- MI — Latah Beds
- Ab — Belt Series (ALGONKIAN TERTIARY QUATERNARY)

IGNEOUS ROCKS

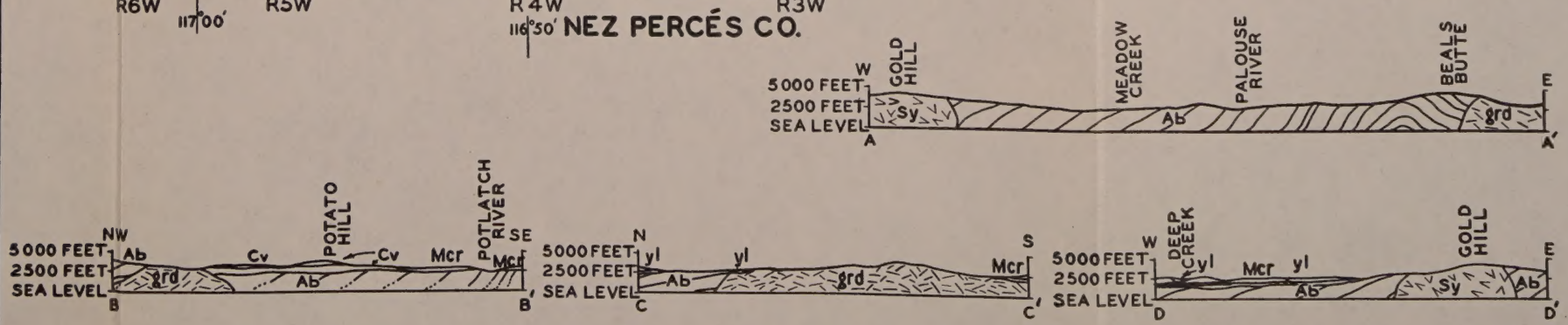
- yl — Younger Lava (MIOCENE OR PLIOCENE)
- Mcr — Columbia River Basalt
- grd — Granodiorite
- Sy — Syenite
- Cv — Volcanics (PERMIAN(?) CRETACEOUS(?) TERTIARY)

SYMBOLS

- Ⓡ Residual clay deposit
- Ⓣ Transported clay deposit
- Ⓑ Basaltic clay deposit
- 60° Strike and dip of beds
- Mine or prospect
- Fault

Geology by Edward L. Tullis, assisted by Walter Northby. Idaho Bureau of Mines and geology, 1931-32. Base from topographic map prepared by Walter Northby and Joe Cremans, 1931-32, and from Land Office plats, U.S. Bur. of Soils, U.S. Forest Service and U.S. Geol. Surv. maps.

STRUCTURE SECTIONS



GEOLOGIC MAP OF LATAH COUNTY, IDAHO